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FOSSIL YAK (*BOS GRUNNIENS:* ARTIODACTYLA, MAMMALIA) FROM THE HIMALAYAS OF PAKISTAN

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ABSTRACT

We describe a maxilla with DP2/-M1/ and associated edentulous mandible for a Quaternary yak (*Bos grunniens* Linnaeus; Bovidae) from Skardu Basin (Northern Areas, Pakistan). The specimen was found in a short stratigraphic section that may represent an alluvial fan. Fossils from high altitudes are rare, and the fossil record for mountain animals is poor. This specimen is the first fossil vertebrate from the Pakistani Himalayas, and one of a few yak fossils known.

Introduction

Skardu Basin is in the Northern Areas of Pakistan on the confluence of the Shigar and Indus rivers. It is approximately 75 km east of Nanga Parbat (the eighth highest mountain in the world) and 80 km southwest of K-2 (the second highest mountain in the world) and forms part of the boundary between the high Himalayas and the Karakorum Mountains (Searle, 1991). Although immediately surrounded by peaks of around 4900 m, base elevation is only around 2200 m (Cronin, 1989). Active uplift continues in this part of the Himalayas, and the basin has been a high altitude environment for all of the late Cenozoic. In spite of this, its geomorphological history is diverse. In the Pliocene and early Pleistocene, glacial deposits, periglacial lakes, and alluvial fanglomerates were deposited (Bunthang Sequence, Cronin et al., 1989). During the last glaciation, the entire basin was covered by a glacial lake when the Indus was dammed by a moraine (Skardu Lake Beds, Cronin, 1989), possibly as late as 30,000 years ago (Schroder et al., 1989).

In May and June of 1994, we undertook a survey expedition to Skardu Basin and its surrounding areas to assess its potential to yield vertebrate fossils. Our intention was to find sediments that might match the fossiliferous Eocene-Oligocene sediments of Ladakh, 100 km southeast of Skardu (Savage et al., 1977; Nanda and Sahni, 1990). Rocks of this age appear to be exposed on the road from Skardu to Kharmang (Khan et al., 1988), but our inspection suggests that they are too heavily metamorphosed to yield fossil vertebrates. Therefore, we redirected our attention to the sediments of Skardu Basin. No fossils have been reported from the sediments of the basin, and these rocks would offer a unique opportunity to sample a late Cenozoic high-altitude fauna.

Material

The recovered fossils are part of the Howard University-Geological Survey of Pakistan collections (H-GSP) and will be permanently housed at the Stratigraphy and Paleontology Branch of the Geological Survey of Pakistan in Islamabad.

We used the following collections of extant mammals for comparisons: CMNH, Cleveland Museum of Natural History, Cleveland, Ohio; UCMP, University of California, Museum of Paleontology, Berkeley, California; USNM, U.S. National Museum of Natural History, Smithsonian Institution, Washington D.C.

Localities

We recovered two fossils, both within sediments at the southeast facing slope of the Marshakala Massif. A terrace of approximately 1 km width extends from the foot of this mountain to the Indus (in the east). This terrace is deeply cut by numerous gulleys with steep bare slopes on the east side of the road. This is Howard-Geological

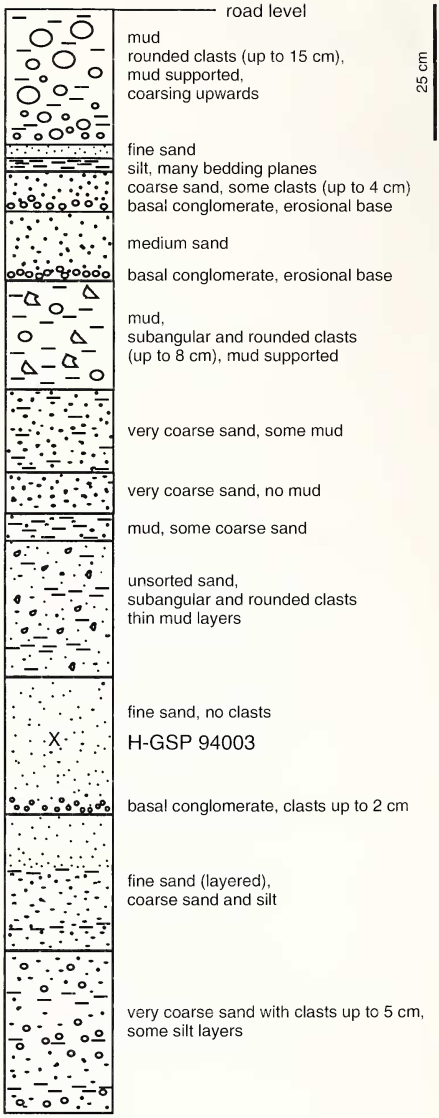

Figure 1. Stratigraphic section of H-GSP Locality 9403 near the foot of the Marshakala Ridge in Skardu Basin. Position of fossil yak (H-GSP 94003) is also marked.

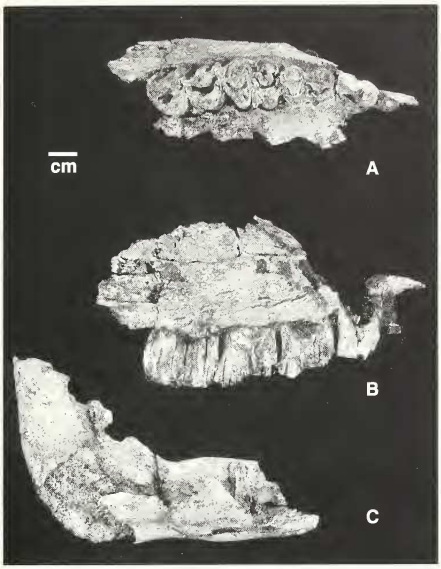

Figure 2. *Bos grunniens*. Fossil yak (H-GSP 94003) from Skardu Basin, unretouched photographs of occlusal (A) and lateral (B) views of right maxilla and associated right mandible in lateral view (C).

Survey of Pakistan (H-GSP) Locality 9403; its coordinates are approximately 35°20′N, 75°41′E. This locality yielded the yak specimen described here (H-GSP 94003). It was found in a north-facing slope in one of the northernmost gulleys near the road. Figure 1 shows a profile taken at the site of the fossil.

Searle (1991, fig. 11.4) mapped the area of this locality as alluvial fan sediments, which suggests that the specimen is of Holocene age. This is the most likely interpretation of the limited amount of geological data available (Schroder, personal communication). Alternatively, it is possible that the bottom of the section of Figure 1 crops out in the Skardu Lake Beds. These deposits form a plain in the basin approximately 30 m above the present Indus (Cronin, 1989) and this would include the elevation of Locality 9403. This would imply that H-GSP 94003 is late Pleistocene in age.

A second fossil was recovered on the west side of the road. Here exposure is mainly along one long escarpment facing northeast and extending from the foot of Marshakala to the road and beyond. This locality (H-GSP Locality 9401) yielded a fragment of a lumbar vertebra (H-GSP 94001) of a bovid, from beds corresponding to the top layers of the profile of Figure 1. It is certainly part of the alluvial fan of Marshakala.

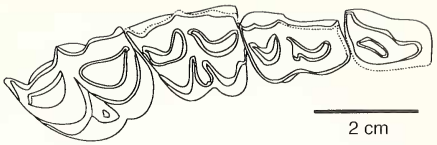

Figure 3. *Bos grunniens*. Fossil yak (H-GSP 94003) from Skardu Basin, outline drawing of right maxillary dentition.

Systematic Paleontology

Order ARTIODACTYLA Owen, 1848
Family BOVIDAE Gray, 1828
Subfamily BOVINAE Gray, 1821
Genus *BOS* Linnaeus, 1758
BOS GRUNNIENS Linnaeus, 1766
Figures 2-3

Description

The mandible (Figure 2) is edentulous, preserving the base of the left ramus and proximal portion of the corpus. The alveolus for the first molar is approximately 27 mm in length and 11.5 mm in width. There is no indication that the second molar is developing within the corpus. The ramus is broken, exposing a broad groove for the mandibular canal that passes immediately caudal to and then directly inferior to the first molar alveolus to lie at the base of the corpus. The preserved base of the ramus is transversely narrow and forms a slightly obtuse angle with the corpus, in a manner similar to the juvenile *Bos grunniens* examined (UCMP 55145).

The maxilla (Figure 2) preserves the alveolar portion which houses DP2-4/, and the first permanent molar. The lateral face of the maxilla bears a low roughened facial tuber, lying roughly 15 mm above the alveolar margin between the DP3/ and DP4/. Erosion of the lateral wall of the maxilla near the maxillary-zygomatic margin exposes a canal (5 mm wide) that extends rostrally. It probably contained the caudal alveolar branch of the trigeminal nerve that travels toward the molar row (Getty, 1975). The palatine process of the maxilla is thick caudally, but tapers to a thin plate rostrally, lingual to the premolars.

It is likely that the thick plate of alveolar bone at the posterior surface of M1/ forms a socket for an erupting M2/, although there is no wear at the caudal margin of M1/ that would imply contact between M1/ and M2/. The first molar is unworn. The tooth is 24.8 mm long and 14.4 mm wide at

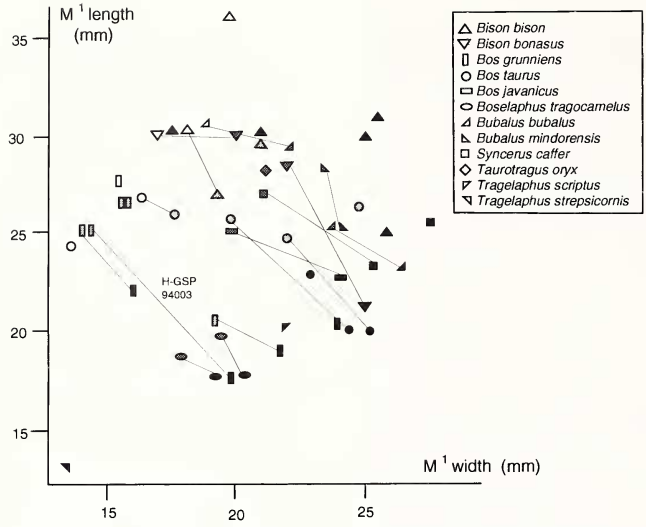

Figure 4. Bivariate plot for length and width of dental measures of M1/'s of Bovini. Included are three species of *Bos*, two species of *Bison*, two species of *Bubalus*, two species of *Tragelaphus*, *Syncerus caffer*, *Boselaphus tragocamelus*, and *Taurotragus oryx*. Unfilled symbols identify occlusal measurements of unworn teeth. Solid symbols identify measurements at the enamel-dentin junction (either measured on extremely worn or broken specimens). Symbols for the same specimen are connected by a line that summarizes shape change of the tooth as a result of wear during its life. Gray figures represent occlusal measurements of worn teeth at the time of death of the animal (i.e. measurements of the occlusal surface of museum specimens). Gray symbols thus represent points on the trajectory connecting unfilled and solid symbols.

its occlusal surface, and 17.5 by 19.8 mm at its base, which is visible on the broken medial side of the specimen. The enamel-dentin junction (EDJ) has not developed, and overall molar shape indicates that the occlusal shape decreases in relative length and increases in relative width during development. This trend was observed to varying degrees in all of the bovids examined (see discussion).

The dentition displays the typical bovid selenodont form (Figure 3). The entostyle (median basal pillar of Gentry, 1970, p. 544) of M1/ is robust, and does not reach the occlusal surface. The labial styles flanking the metacone are more strongly developed than the parastyle, although the latter cusp is larger than the metacone. DP4/ also bears a well developed entostyle, and is both shorter (17.0 mm) and narrower (17.5 mm) than the first molar as measured at the EDJ. All four cusps are equally well developed. In DP3/, both the proto- and paracone are reduced bucco-lingually, while the hypo- and metacone are wider than the anterior cusps, making the rostral half of the premolar longer and narrower than the caudal half. Overall, the maximum length and width of DP3/ are 17.9 mm and 15.3 mm. Only the metastyle of the DP3/ is well developed. DP2/ bears a small paracone, a metacone, and its protocone is larger than in DP3/. It does not have a hypocone, and only the metastyle is strong. The tooth is narrow and long, its length is 16.2 mm, its width 11.5 mm.

Discussion

Bovids form a distinct, diverse, and important family, but their classification at levels below the family remains in dispute. We follow the subfamily classification of Wilson and Reeder (1993). The most diagnostic osteological characteristics of the members of the Bovidae are in the horncores (Pilgrim, 1937; Koenigswald, 1986), although dental characteristics can be of limited usefulness (Gentry, 1970). Large size and presence of a large entostyle suggest that H-GSP 94003 pertains to the subfamily of cattle: Bovinae. Wilson and Reeder (1993) included the extant genera *Bison*, *Bos*, *Boselaphus*, *Bubalus*, *Syncerus*, *Taurotragus*, *Tetracerus*, and *Tragelaphus* in Bovinae. Of these, extant and fossil forms of *Syncerus*, *Taurotragus* and *Tragelaphus* are restricted to Africa and Arabia (Gentry, 1970), and it is unlikely that H-GSP 94003 pertains to these.

The fossil record of Bovinae in Indo-Pakistan is extensive (Pilgrim, 1937; Simpson, 1945), but most of these bovids are restricted to the lowlands and are thus unlikely to be found in the Skardu Basin. Among these are *Tetracerus*, which is also small and lacks an entostyle, and *Boselaphus*, which matches H-GSP 94003 in size but either lacks entirely or retains a very small entostyle (USNM 144075, 269127). The remaining extant genera, *Bison*, *Bos*, and *Bubalus*, and their Pleistocene relatives, such as *Leptobos* and *Hemibos*, are essentially indistinguishable on the basis of tooth shape. The modern species of *Bos* and *Bubalus* that occur on the Asian mainland do not live in high altitude environments (Nowak, 1991), with the exception of the yak, *Bos grunniens*. Fossil large bovids are also only known from lowland environments, although the fossil record from high altitudes is so scarce that this cannot be taken as evidence for their absence.

Olsen (1990) reviewed the fossil record for yaks and discussed some of their morphological differences with other bovids. His figures of dentitions show great differences in the occlusal morphology between the modern genera of large Bovinae. These differences, such as the squareness of teeth, are due to individual age of the animals as suggested by Olsen. The yak that is figured was a dentally aged animal, with an M1/ that had nearly lost its internal enamel folds. The *Bos taurus* specimen that Olsen (1990) figured lost its P2/ after death (given that its alveolus is visible), and his *Bubalus* is a young individual that retains a DP4/ with four cusps (instead of a P4/ with only two).

The fossil record for yaks is poor; few Pleistocene specimens are known from high elevations of Central Asia (Olsen, 1990). There is no consensus on how to distinguish (dental) remains of *Bison*, *Bos*, and other large bovines from late Cenozoic of Asia, leaving the evolutionary history of the yak uncertain. This is significant because molecular evidence suggests that the sister group of *Bos grunniens* is *Bison bison*, and not *Bos taurus* (Miyamoto et al., 1989).

Size can be used to distinguish between the extant species of Bovinae to some extent. Figure 4 shows M1/ size distribution for several Bovinae. For each specimen, length and width were measured at the occlusal surface and at the enamel-dentin junction (when it was visible). Because bovid molar dimensions change with wear, there are only two wear stages that are independent of age and at which animals can be compared directly: at the occlusal surface of unworn teeth (unfilled symbols) and at the enamel-dentin junction (solid symbols). Occlusal "ontogeny" results from wear and open and closed figures represent its extremes. These extremes are connected by an ontogenetic wear trajectory, indicated diagrammatically as straight lines in Figure 4. In teeth that have been in use, the unworn dimensions cannot be determined and we therefore measured these teeth at the occlusal surface. If the lines represent the true ontogenetic trajectory, than the dimensions of the occlusal surface of a worn tooth (gray symbols) will be on this line. They represent the wear stage at the time of death.

While size comparisons cannot be used as the sole identifier among bovine teeth, comparing the occlusal ontogenies of different bovines suggests that the most likely identification of H-GSP 94003 is *Bos grunniens*. It is close in its overall dimensions to the six yak specimens that we measured (UCMP 55145, USNM 14328, USNM 257034, USNM 270919, USNM 296176, USNM 396176). Its final wear stages are similar in size to *Boselaphus*, but this genus differs morphologically in having a small or absent entostyle. The only other bovid that comes close in size to H-GSP 94003 is a domestic dwarf bull (*Bos taurus*, USNM 17971, open circle near y-axis). It is unlikely that the fossil represents a dwarf bull, but the specimen does show the size plasticity among bovines.

Not only do the M1/ dimensions of H-GSP 94003 match those of modern yaks, the deciduous premolars are also similar in size to the only deciduous yak premolars we could measure. In UCMP 55145 DP2/ was 16.2 by 9.3 mm, DP3/ was 19.1 by 13.2 mm, and DP4/ was 19.0 by 16.2 mm.

The evidence for identification of H-GSP 94003 is circumstantial but firm. Morphological traits, the size of entostyle and labial styles identify the specimen as pertaining to *Bison*, *Bos*, *Bubalus*, *Syncerus*, or their immediate fossil relatives. The habitat in which the animal must have lived suggests strongly that it was a yak, and the size data on the teeth confirm this identification.

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